Improving VHT MU-MIMO Communications by Concatenating Long Data Streams in Consecutive Groups

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Roadmap

- Comparison between 802.11n and 802.11ac
- Overview of VHT MU-MIMO communication technologies
- VHT MU-MIMO communication
- Concatenating long data streams into groups
- Simulation results
- Conclusion and future work
- References

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Comparison of 802.11n and 802.11ac Standards

802.11n		802.11ac
Physical layer:		
▪ 2.4 GHz and 5 GHz	→	▪ 5 GHz only
▪ 20 MHz and 40 MHz	→	▪ 20 MHz, 40 MHz, 80 MHz, and 160 MHz
▪ Modulation rate 64 QAM at coding rate of 5/6	→	▪ Modulation rate of 256 QAM at coding rate of 5/6
Data Link layer:		
▪ A-MSDU and A-MPDU Frame Aggregation	→	▪ A-MPDU Frame Aggregation
High Throughput (HT) Communication Mode		**Very High Throughput (VHT) MU-MIMO Communication Mode**
▪ Transmission of maximum 4 data streams to a single STA	→	▪ Transmission to 4 STAs simultaneous with maximum 4 data streams per ST

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Frame Aggregation and Block Acknowledgement

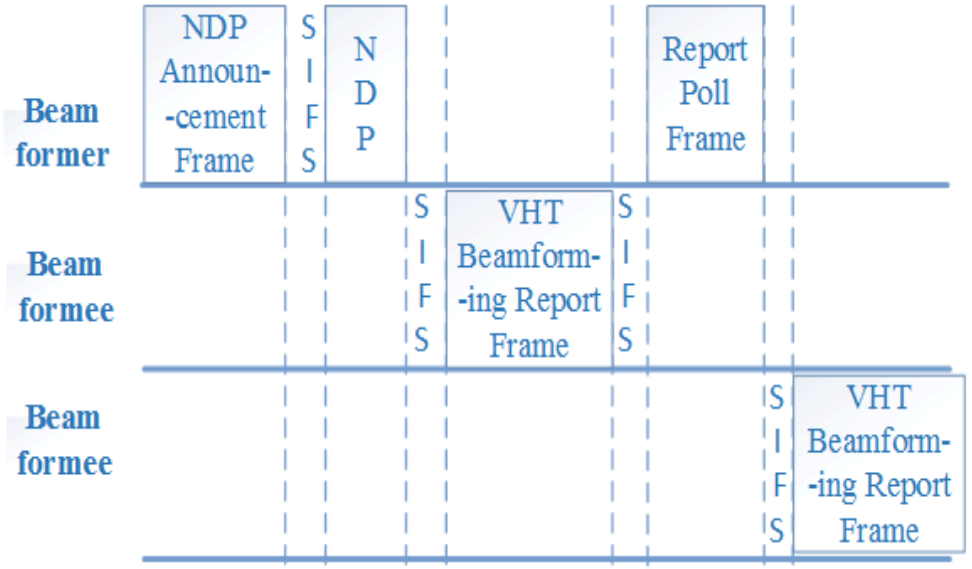
- Previous standards: one frame transmitted at a time over the channel
- Ineffective ratio of channel overhead and data payload
- Frame aggregation suggests transmission of multiple frames of payload along with one time overhead
- Frame aggregation (two levels):
  - Aggregated Multi Service Data Unit (A-MSDU)
  - Aggregated Multi-Protocol Data Unit (A-MPDU)
- 802.11ac only uses A-MPDU
- Block Acknowledgement: acknowledges all frames successfully received inside an A-MPDU

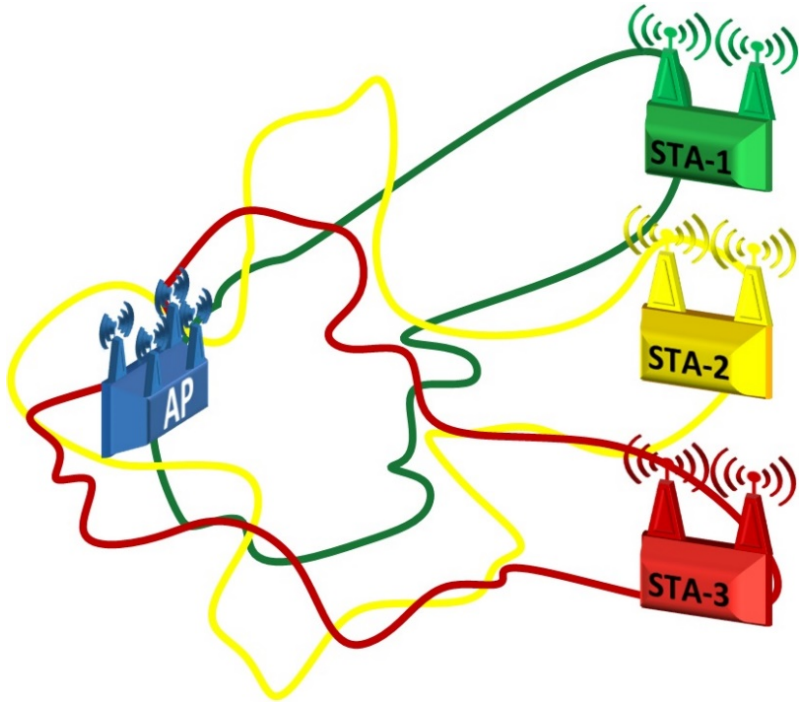
Table 1. 802.11ac A-MPDU Si

Serial No.	A-MPDU size (oct
1	8,191
2	16,383
3	32,767
4	65,535
5	131,071
6	262,147
7	524,287
8	1,048,575

VHT Sounding Protocol

- Explicit beamfroming mechanism: a beamformer sends a Null Data Packet (NDP) to a beamformee.
- The beamformee receives the NDP, creates a steering feedback, and sends it to a beamformer. Used by beamformer to prepare steering matrix.
- The matrix provides steering of space-time streams in a direction of the recipient STA and nullifies the propagation to be received by other STAs.



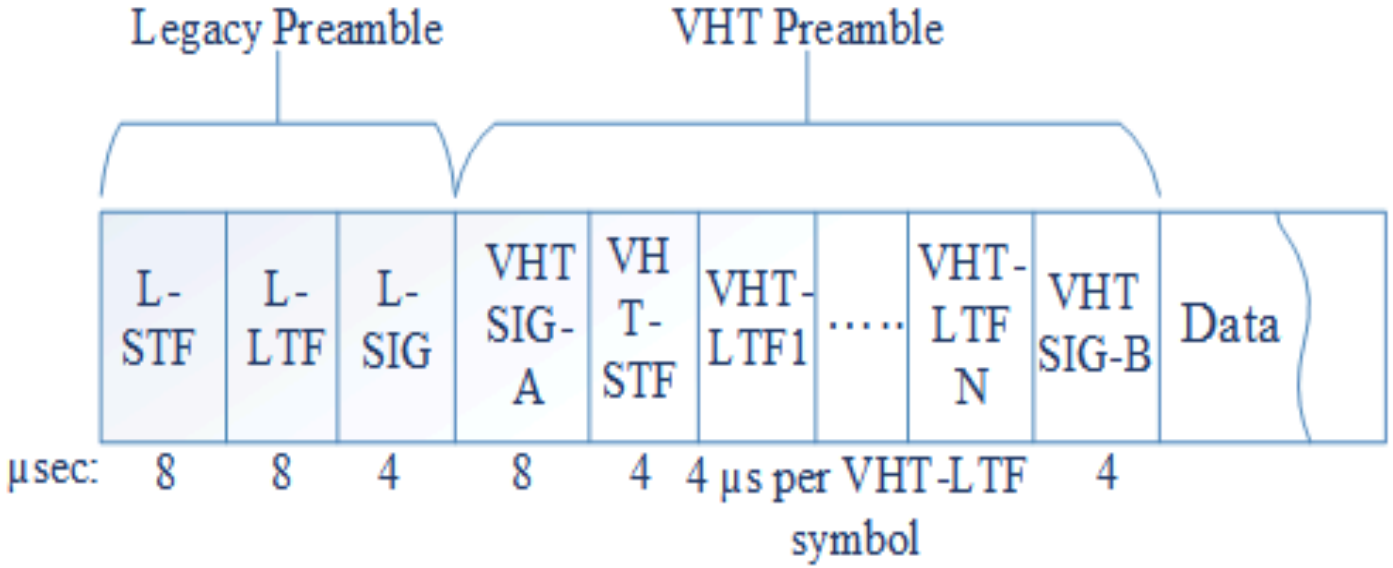


Group ID Assignment

- Access Point assigns a Group ID and a User Position ID to STAs.
- Group ID: assigned to up to four STAs. Each STA has a different User Position ID.
- An STA may be assigned multiple Group IDs. However, within the group, the User Position IDs are unique.
- Assignments of Group IDs are communicated to STAs via the “Group ID management frame”.

Very High Throughput (VHT) Preamble

- A new preamble is transmitted after a Legacy Preamble.
- Enhanced specifically to accommodate simultaneous multi-user transmissions over the same channel.
- VHT Preamble has two signaling fields: VHT SIG-A and VHT SIG-B.
- VHT SIG-A carries the collective information required by STAs of a group.
- VHT SIG-Bs are propagated in the direction of STAs.



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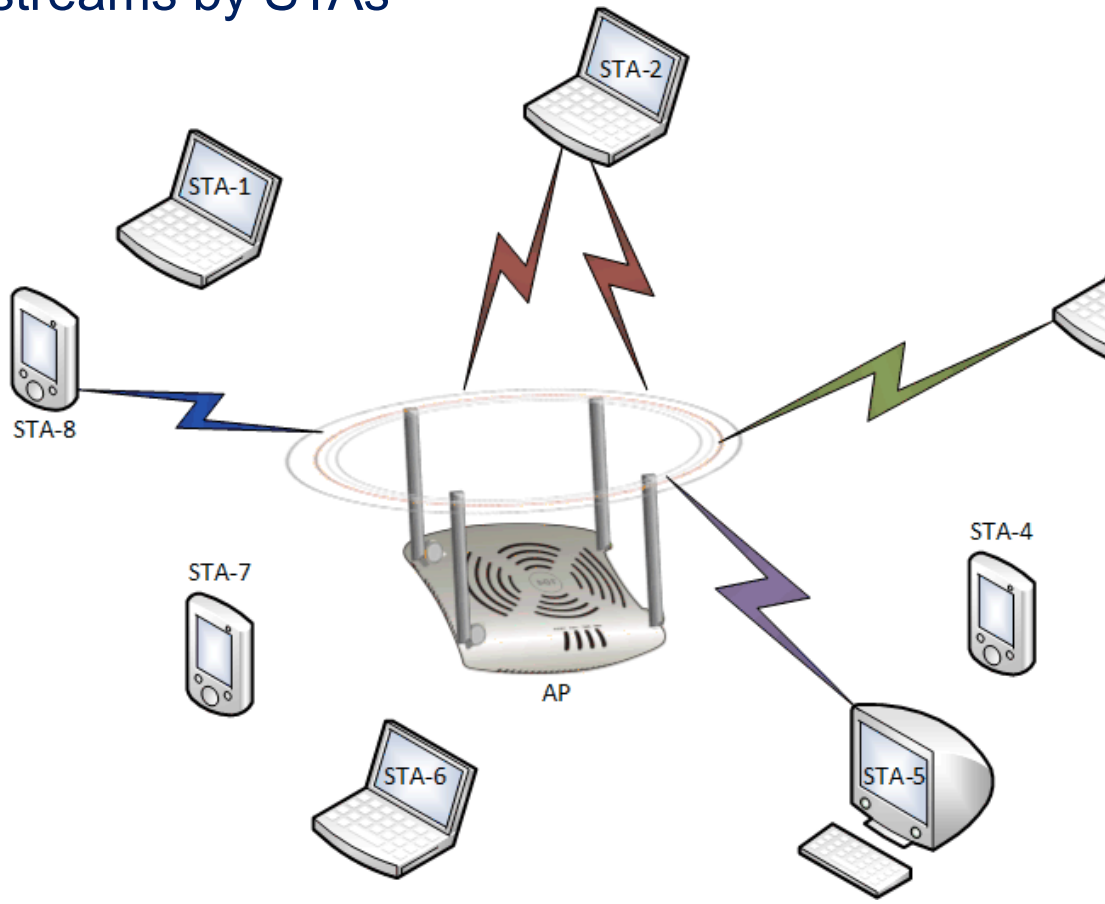
VHT MU-MIMO Communication

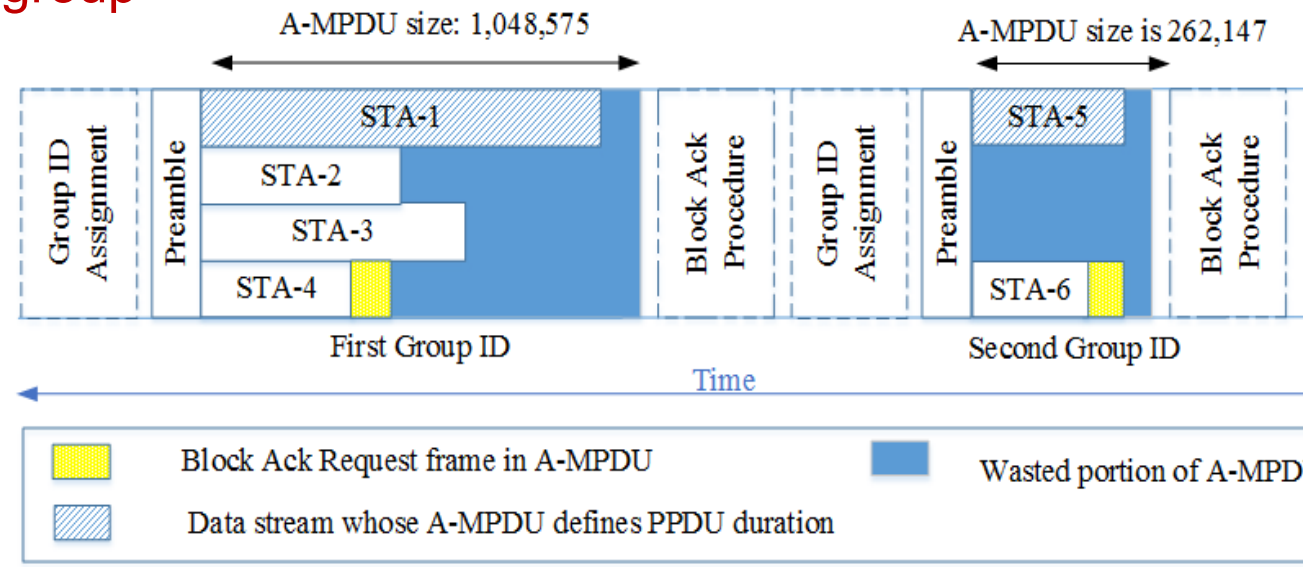
- AP in a downlink simultaneously transmits multiple streams of data to multiple STAs over the same channel width.
- The successful extraction of their own streams by STAs is the result of beamforming.
- Space-time streams of a particular STA are directed toward the STA while streams of other STAs are nullified in its direction.



VHT MU-MIMO Communication: Example

VHT MU-MIMO Communication process of six STAs:

- Assumption: All STAs communicate with the same MCS index
- AP has collected steering feedback of all STAs using the VHT sounding process
- Selects STAs for first group
- Selects A-MPDU sizes for every STA MPDU
- Calculates PPDU duration of every space-time stream
- Decides PPDU duration of the group (the largest A-MPDU size)



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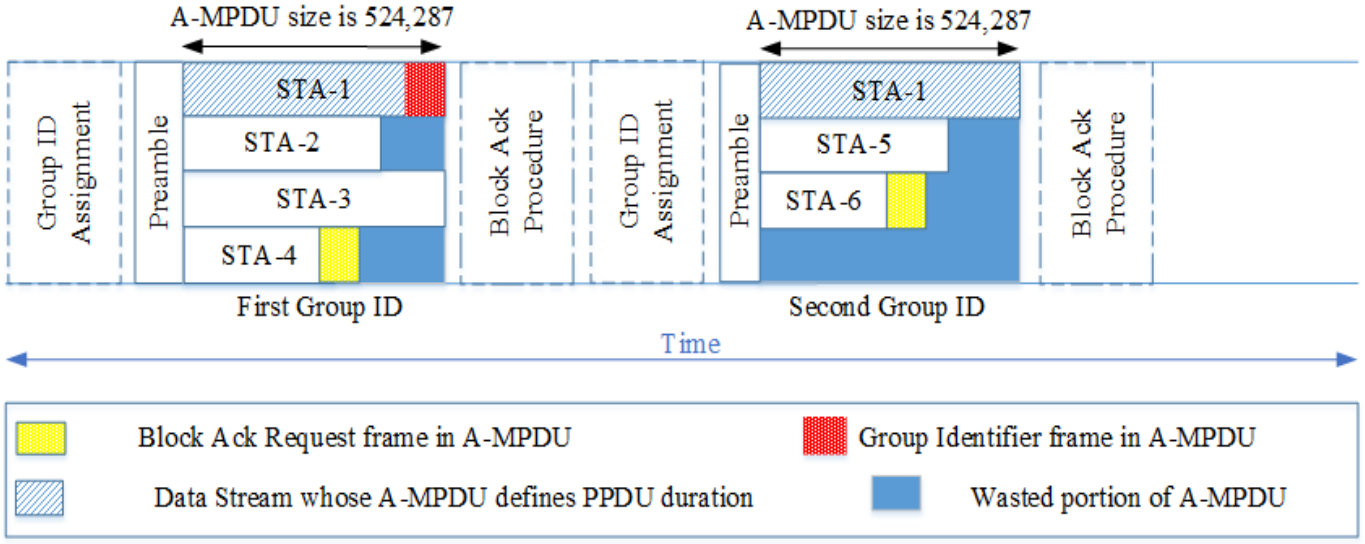
Concatenating Long Data Streams into Groups

Selection of the PPDU duration:

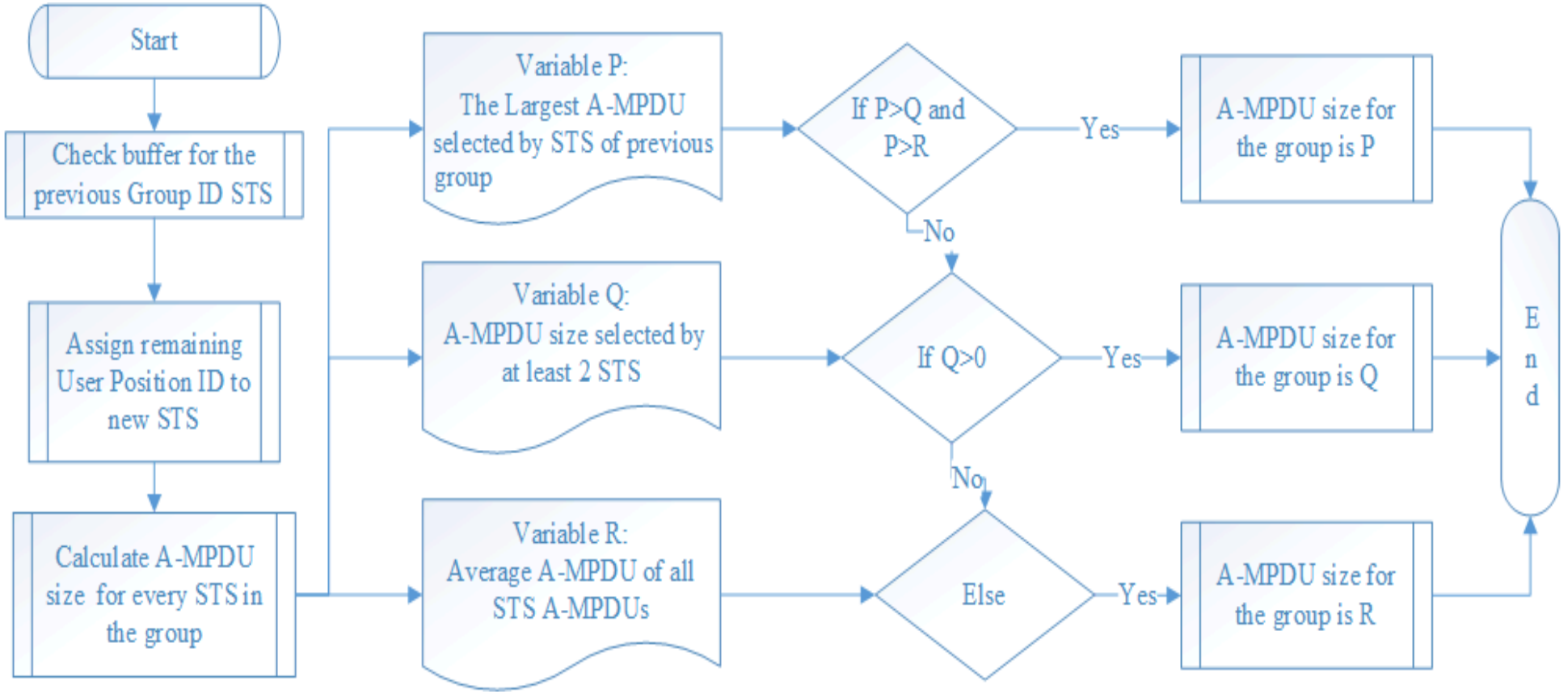
- Calculate the average of selected A-MPDUs of data streams and select the A-MPDU size that fits the calculated average.
- Reduce the size of the long data streams to the selected A-MPDU size and append a Group ID assignment frame.
- Calculate PPDU duration of the group based on the average A-MPDU.
- Transmit the remaining part of a long data streams in the next Group ID.



Concatenating Long Data Streams into Groups (cont.)

In two cases, the average of A-MPDUs is not selected as the A-MPDU size for the group:

- data stream in the first group is part of previous group
- two data streams select similar A-MPDU size



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Simulation Results: Transmission Time

- Generate 100 data streams of random sizes ranging between 2,000 and 1,048,575 oc
- Calculate transmission time:

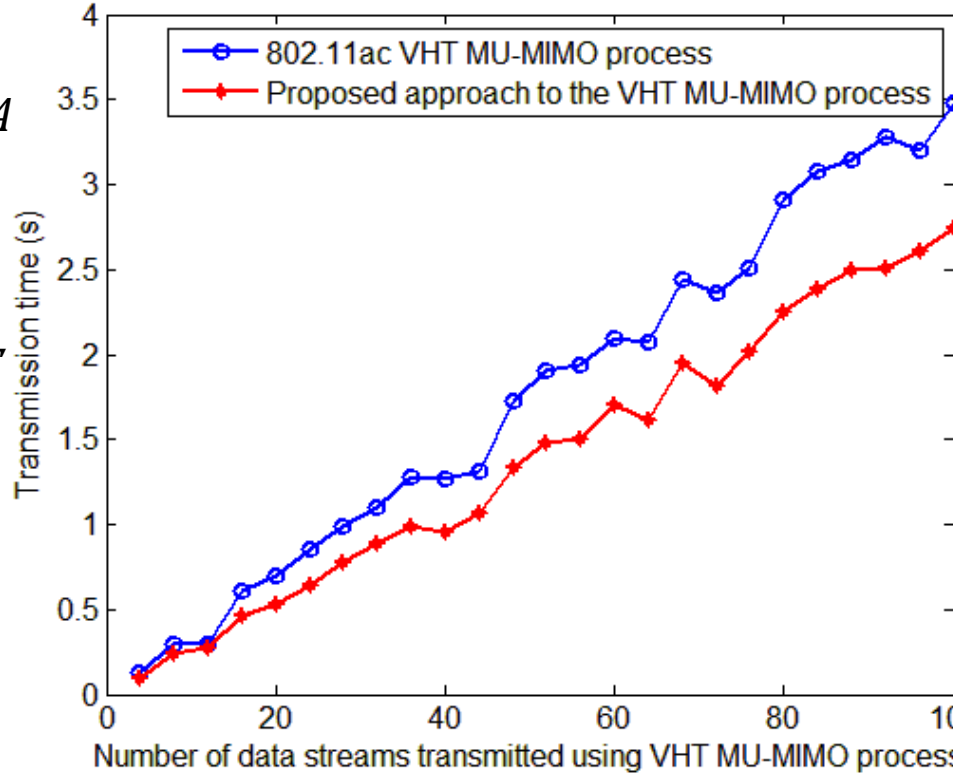
$$TXTIME = T\downarrow LSIG\_PR + T\downarrow L-SIG + T\downarrow VHT-SIG-A + T\downarrow VHT-PR + T\downarrow VHT-SIGB + T\downarrow SYML \times N\downarrow SYM$$

The preambles value:

$$T\downarrow LSIG\_PR + T\downarrow L-SIG + T\downarrow VHT-SIG-A + T\downarrow VHT-PR + T\downarrow VHT-SIGB = 40\ \mu s$$

The NSYM of the data A-MPDU:

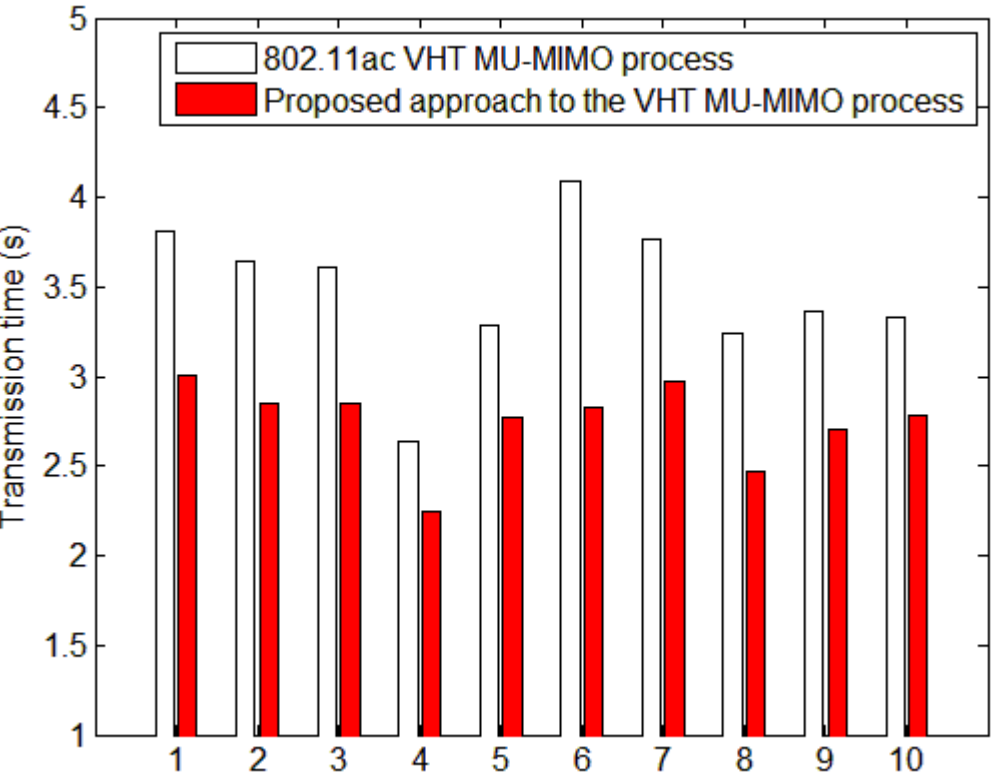
$$N\downarrow SYM = m\downarrow STBC \times \lceil (8 \times APEP\_LENGTH + N\downarrow service + N\downarrow tail \times N\downarrow ES) / (m\downarrow STBC \times N\downarrow DBPS) \rceil$$

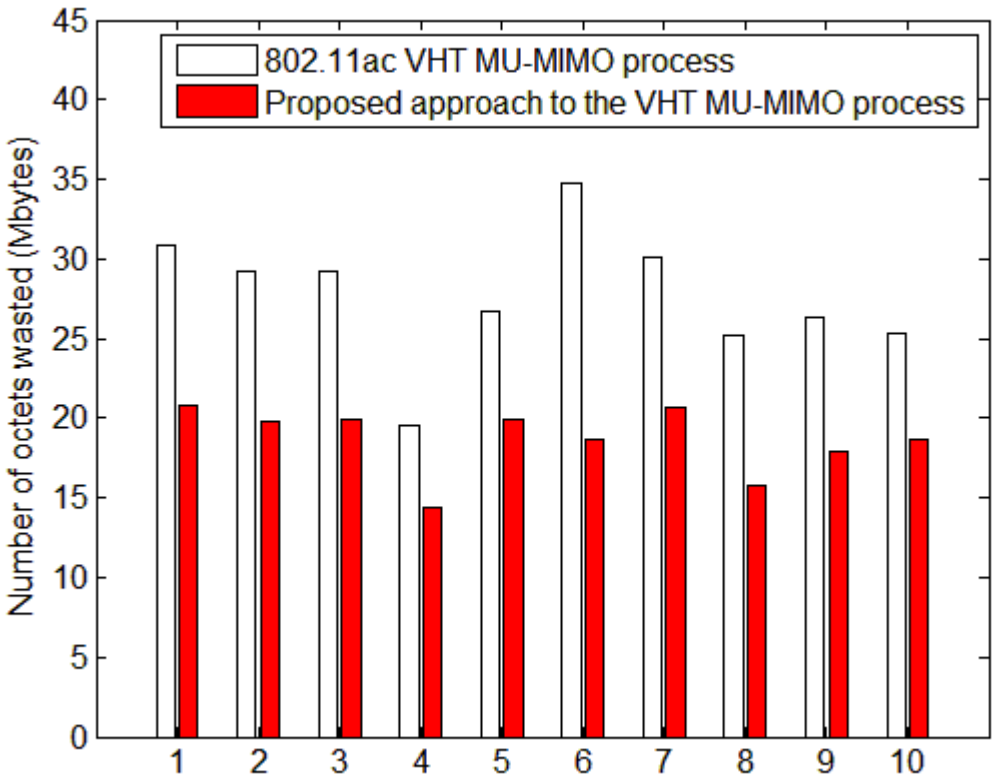


- TSYML = 4, mSTBC = 1, Nservice = 16, Ntail = 8, NES=1, NDBPS= 104, and APEP_LENGTH = A-MPDU size is selected from Table 1 for STAs within a group.
- We compare results of the standard VHT MU-MIMO communication process and the proposed approach.

Simulation Results: Transmission Time and Wasted Octets

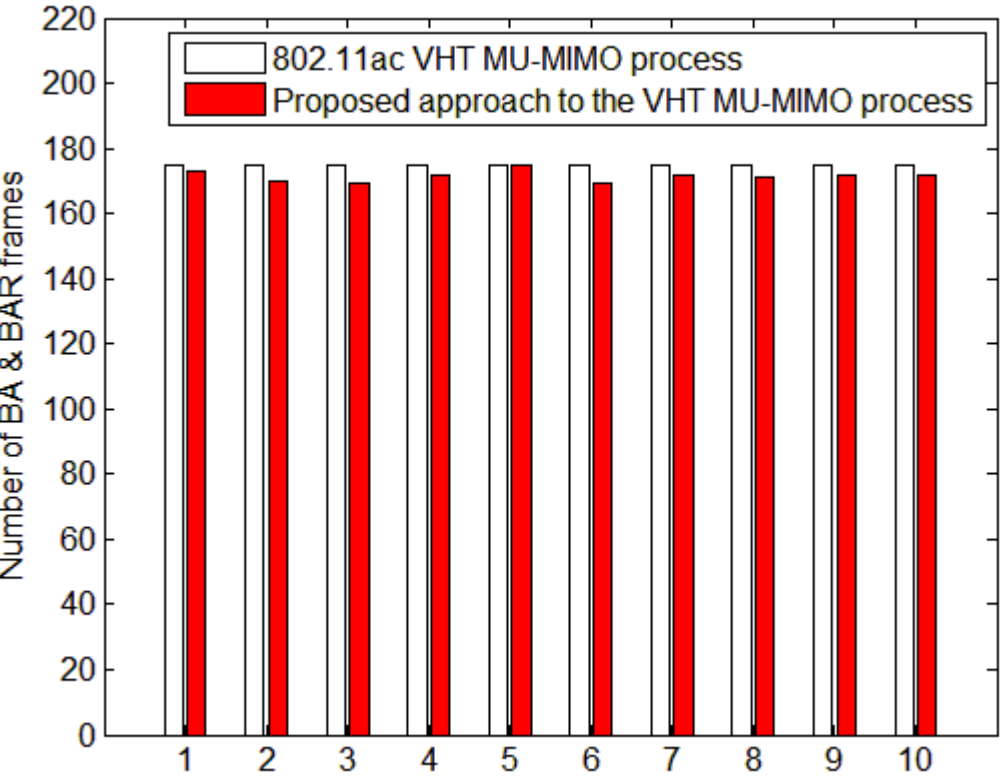
- Ten iterations with hundred random data streams:

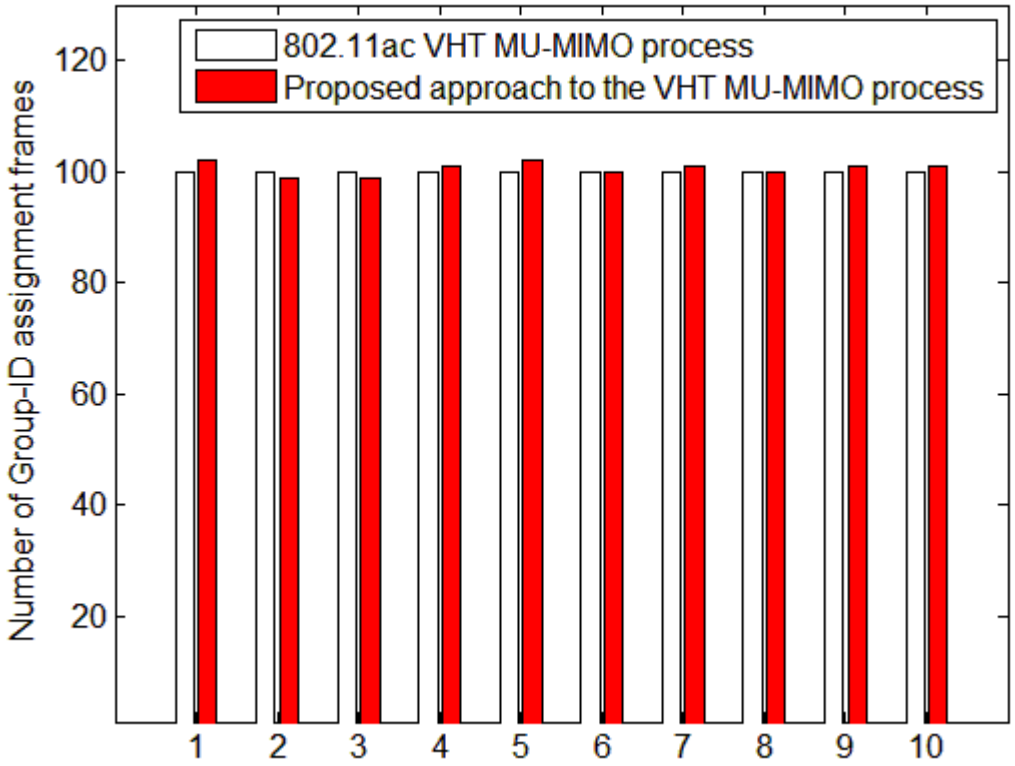




Simulation Results: Control and Management frames

- Ten iterations with hundred random data streams:





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Future Work

- Assumption: all STAs agree on the same MCS index implies that all STAs are at equal distance and receive signals of equal proportion.
- The maximum PPDU duration of a data stream defines the PPDU duration of the group.
- PPDU duration of data streams are functions:
  - A-MPDU size
  - MCS index (distance/position)
-
  -
    a group;
  - selecting A-MPDU size of a long data stream that fits the PPDU duration when manipulated with its MCS index;
  - transmitting the remains of long data stream in the next consecutive group.

Future Work

A-MPDU size (octets)	PPDU duration with out preamble (μs)							
8,191	10,125	5,083	3,402	2,561	1,721	1,301	1,161	1,049
16,383	20,207	10,124	6,763	5,082	3,401	2,561	2,281	2,057
32,767	40,372	20,206	13,484	10,123	6,762	5,082	4,521	4,073
65,535	80,702	40,371	26,927	20,206	13,484	10,123	9,003	8,106
131,071	161,360	80,701	53,814	40,370	26,927	20,205	17,965	16,17
262,143	322,680	161,360	107,590	80,700	53,814	40,370	35,889	32,30
524,287	645,320	322,680	215,130	161,360	107,590	80,700	71,738	64,56
1,048,575	129,060	645,325	430,230	322,680	215,130	161,360	143,440	12,91
NDBPS value	**26**	**52**	**78**	**104**	**156**	**208**	**234**	**260**
MCS index	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Modulation-Rate	**BPSK - 1/2**	**QPSK - 1/2**	**QPSK - 3/4**	**16-QAM - 1/2**	**16-QAM - 3/4**	**64-QAM - 2/3**	**64-QAM - 3/4**	**64-QA 5/6**

Conclusion

- Explored the VHT MU-MIMO communication mode with its supporting technologies.
- Proposed a solution to reduce wasting a portion of an A-MPDU of a short data stream in a group of unequal streams by concatenating longer data streams in consecutive groups.
- Considered selection of PPDU duration of a group as function of A-MPDU size and divided the A-MPDU of long data stream to the average of the entire group while the next consecutive Group ID is assigned within the A-MPDU.
- After the Block Acknowledgement procedure and Group ID assignment to new STAs, remaining data of the long data streams are transmitted together with the new data streams.
- Simulation results show significant improvement in transmission time and efficient space-time utilization of the channel with no additional overhead of control and management frames.

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